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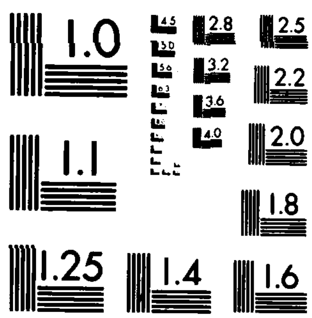

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Defence and Civil Institute of Environmental Medicine

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BATTERY OF CANDIDATE PHYSICAL TESTS FOR CONSIDERATION AS OCCUPATIONAL PHYSICAL SELECTION STANDARDS FOR CANADIAN FORCES TRADES

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ABSTRACT

Central to the development of occupational physical selection standards for trades in the Canadian Forces is the study of the relationship between man's physical attributes and his physical performance capabilities. A battery of tests, pertaining to the physical attributes of strength, anthropometry and endurance, has been compiled. The tests, selected from the literature, were those with a demonstrated relationship with work performance. The performance of male and female subjects on these physical tests and on job-related tasks, representative of the physical demands of the trades, will be compared. Those candidate tests which exhibit a practical predictive relationship with the tasks will be selected for the development of physical selection standards for trades in the Canadian Forces.

INTRODUCTION

Many trades in the Canadian Forces (CF) are physically demanding, limiting the number of individuals who can perform the duties associated with these trades. Physical standards may assist in the effective assignment of personnel to the various trades. The value of physical standards is of interest to the industrial sector as well as the military. Efforts to develop physical standards have been attempted in a variety of civilian occupations (1-5). Currently, military groups, such as the United States Air Force, Army and Navy, are each separately studying the prospect of screening individuals using physical selection standards (6-10).

DCIEM has been tasked to study the physical requirements of three CF trades; Weapons Technician (Air), Weapons Technician (Land) and Mobile Support Equipment Operator. The purpose of this tasking is to provide the Canadian Forces Training System Headquarters with valid physical selection standards for these trades. In addition, this work serves as a pilot study for a more comprehensive tasking to develop occupational physical selection standards (OPSS) for all trades in the CF.

It is not feasible to screen each recruit using all of the physically demanding tasks of each trade. Therefore, criterion tasks representative of the physical demands of each trade were compiled. They involve predominately manual materials handling activities (MMHA), corroborating the finding of a USAF study that 90 percent of the tasks perceived by the incumbents to be stressful involved MMHA (6). There are six basic types of MMHA: lifting; lowering; pushing; pulling; carrying; and walking (11). Since the criterion tasks for the three trades under investigation contain several lifting and lowering movements, many of the physical tests selected for the battery are specific to these movements.

This paper proposes a battery of candidate physical tests and measures selected on the basis that they are biomechanically related to the requirements of the criterion tasks. Correlations between the performance on the criterion tasks and the performance on the physical tests will be examined. Those physical tests and measures which show a practical, predictive relationship to the criterion tasks, will be used in the final selection standards for the three trades.

REVIEW OF THE LITERATURE

Physical tests have been used in industry, athletics and the military to predict a person's capability to perform physical tasks (1-5,12,13). A review of the factors which should be considered when assessing human physical capabilities has been completed in preparation for the development of OPSS (14). Many factors, including psychological, neurophysiological and physical have been shown to affect an individual's performance (5,15,16). The present study limits its scope to the physical factors. Man's primary physical attributes can be divided into three categories; strength, anthropometry and endurance (6). Each of these areas was extensively reviewed and appropriate tests were selected for inclusion in the test battery.

1. Strength

Muscular strength can be defined as the ability of a muscle or muscle group to exert a maximal force (17). Strength testing is important because it can provide an effective method of predicting an individual's capability of performing a physical task (18). The assessment of strength, both in terms of the physical requirements of a task and the physical capability of individuals, can be used to increase the effectiveness of manpower management and career planning, reduce the risk of job-related injury , and establish population norms for the improved design of tools and equipment (1,3,18,19).

Strength is a complex entity. Therefore, in determining which strength tests should be included in the testing battery, the different types of strength and the specificity of strength had to be considered. Fundamentally, there are two methods for measuring strength; static (isometric) and dynamic (isotonic) (20-23). Static strength is the tension in the muscle when it contracts against an outer resistance, which is immovable (20). Dynamic strength is equal to the load that can be moved a given distance (21). Dynamic strength can be further divided into two categories. The first is an explosive manoeuvre involving only one action; the second involves prolonged or repeated actions (8,24).

There are conflicting views in the literature as to the relationship between static and dynamic strength (20,22,23,25-31). A review by Laubach revealed a large correlation range from -0.25 to 0.99 (32), between static and dynamic strengths. The low correlations may be due to varying testing procedures, therefore causing the comparison of very different activities (22). Carlson (23) studied the relationship between the isometric and isotonic strength of the right elbow flexor muscles. He concluded that tests of both strengths have been shown to successfully discriminate between strong and weak individuals, but the absolute values of the two strengths are significantly different (23).

Strength is highly specific (33,34), and the concept of strength specificity refers to several different aspects. The differences between static and dynamic strength emphasise one aspect. The different definitions of strength have led to different methods of measuring it. Since elements of both static and dynamic strength are part of the criterion tasks, tests of both strengths are required in the testing battery.

Specificity is also evident in the different measured strengths of the various muscles and muscle groups of the human body. In the literature, many strength scores have been used, including arm, leg, back and composite strength scores. Since the correlations between the strength of different muscle groups have been low (20), this paper must take into consideration which strength scores will best parallel the results of the criterion tasks.

Finally, strength results will be specific to the testing procedures (33). Two major procedural variables have been identified and they act by changing the relationship of the muscle or muscle group and the corresponding lever system. Body positioning, including posture and joint angles, comprises the first variable (17,18,21,35-55) The second variable is the amount of stabilization or support allotted to the subjects by aids, such as arm rests or seat belts (42,53,54,56,57). Standardization of the testing procedures, to ensure all subjects are tested under similar conditions (19,21,33,34), should result in more meaningful comparisons of the data.

But standardization is not only necessary for the actual testing procedures, it is important in the reporting and presentation of the results of a study. This will also help to ensure comparable data between different studies. Descriptions of the presentation of the measurements, tests, condition of the subjects and the data are summarized in Appendix A.

Strength Measures

A single strength measure may be a meaningless value in practical terms (8,32). Because of the specificity of strength, it would not be valid to estimate a person's overall muscular strength from strength measurements involving one single group of muscles (18,20). A battery of tests, carefully chosen to be biomechanically related to the requirements of the criterion tasks, would be more appropriate (18). In order to obtain a measure of composite strength, the proposed strength tests include a variety of static and dynamic tests. In Appendix B, the static and dynamic tests are described in detail.

Static

1. right and left grip strengths
2. lifts at five different vertical heights
3. back extension
4. back flexion
5. shoulder flexion (45 dgrees)
6. shoulder flexion (135 degrees)
7. elbow flexion
8. arm pull

Dynamic

1. chin-ups
2. push-ups
3. dips
4. sit-ups
5. vertical leap

It can be noted that static tests constitute the major portion of the strength battery. There are two important reasons for this. First, standardization of static tests is less complicated than dynamic tests, simply because the testing positions and procedures are more easily reproduced. In contrast, dynamic strength testing involves body motion, for which potential error may be introduced by factors such as body posture, joint position and accelerations of various limb parts throughout the range of motion (18,20). Secondly, static strength testing is less time consuming, less fatiguing and safer for the subject (18,20). In principle, maximum static strength can be determined by one single maximum contraction. But, several trials with increasing loads are necessary to find the maximum strength using the dynamic method (20), and this can increase the possibility of fatigue and, in turn, injury.

The problems of increased time consumption, fatigue and risk of injury involved with the dynamic testing method required consideration. One attempt to alleviate these problems was to select tests which do not require the movement of an external weight, but use the subject's own body weight. The tests are completed once and the number of successful manoeuvres over a given time period is recorded. Since the subject's own body weight is used, the strength scores are measures of relative strength, which differs from absolute strength. Comparisons between the strength scores of the subjects may not appear to be valid because the resistance, i.e. body weight, varies from subject to subject. However, there is a standardized element in the chin-up, push-up, sit-up and dip tests and that is time. Some of the performance scores of the criterion tasks are also based on time. The dynamic tests of relative strength, standardized by time, may show a close relationship to the time-based criterion tasks.

Strength Indices and Models

In the literature, many strength measures have been combined to form strength indices and models in an attempt to more accurately represent the strength capability of a given body segment and possibly increase the predictive power of some measure of performance (1,16,19,58-61). The strength indices and models, adapted for this study, appear in Appendix B.

The models combine measures of strength and anthropometry (see section: Anthropometry). They deal primarily with the

MMHA of lifting. There are lifting tests in the test battery, so that lifting strength can be directly measured. If the models show practical, predictive relationships to the measured lifting strength values, then they can be used to estimate lifting strength. This would reduce the number of tests required in the testing battery and possibly remove tests which are potentially more strenuous to the subjects.

Static Strength Measuring Apparatus

A strength testing apparatus has been constructed to measure the maximal isometric strength of different muscle groups. A complete description of the testing apparatus and the recording instruments appears in Appendix B. Briefly, a load cell, which measures force, is affixed to the base of the strength device. A cable, chain and nonstretchable belt provide the connection from the subject to the load cell. The electrical output from the load cell is recorded on an X-Y plotter.

Standards for taking static strength measurements have been established in the literature (20,57,62). The reported time span, for a voluntary maximum exertion, varies from one second, if only one articulation is involved, to four or six seconds, if several muscle groups are involved (20,57,62). The collection of data for at least four seconds is necessary to obtain a steady-state exertion over a three second interval. By averaging the data over a three second steady-state interval, errors induced by tremor and motion dynamics will be avoided (49). If a contraction is sustained for more than eight to ten seconds, fatigue from hypoxia and metabolite accumulation may occur (63). Therefore to limit the errors caused by fatigue, a maximum exertion of four seconds will be implemented during the trials and adequate rest periods of at least two minutes between consecutive exertions will be used (18,62).

2. Anthropometry

Anthropometry is important because it can affect the mechanics of a movement in two ways. First, anthropometric measures are intimately involved in the relationship between the muscle or muscle group and the corresponding lever system responsible for a given movement. Second, the restrictions of the workspace may affect the performance of a movement by favouring certain individuals because of their specific anthropometric dimensions. The relationship between the strength data and the anthropometric data will also be investigated. A review of the literature suggests that significant correlations may exist between certain strength and body measurements (1,19,28,30,46,48,51,53,64-87).

Anthropometric Measures

Thirty-three anthropometric measures, in addition to age and gender, will be recorded for each subject. As suggested by Ouellette, et.al. (88), these anthropometric measures were selected because of their relatedness to the criterion tasks and the physical tests. A description and illustration of each measure appears in Appendix C.

Some of these measures will be evaluated directly as limiting factors of performance and therefore important as physical selection standards. A number of anthropometric indices will be derived from the anthropometric measures using the formulae described in Appendix C. These indices, adapted from the literature, have shown a relationship to certain strength measures. The greater portion of the anthropometric measures will be combined with strength measures to form predictive indices and models (see Appendix B).

3. Endurance

The speed at which a task is completed is important as a limiting factor to performance (15,16). Dynamic strength by definition involves movement. The time taken to complete a dynamic strength manoeuvre may range from one quick action to several repetitions (8,24). In general, the dynamic strength tests, mentioned in the literature, are measured over a short period of time (1 minute) and a sustained endurance element is missing (6,43). Similarly, tests of static strength tend not to involve prolonged contractions.

To measure the ability of the subjects to perform over long periods of time, a separate test is required. The most popular evaluation of endurance is the measurement of maximal aerobic capacity while exercising on a treadmill or bicycle ergometer (63). It has been shown that repetitive lifting causes a response of the cardio-pulmonary functions similar to that induced by treadmill and bicycle ergometer exercise (89,90). Therefore, a measure of maximal aerobic capacity should show a relationship to the performance of a repetitive MMHA, such as lifting.

Endurance Measure

To assess an individual's maximal aerobic capacity, a maximal test is not necessary (63). A step test, using heart rate as its criterion measurement of oxygen consumption, can be implemented to evaluate a subject's maximal aerobic capacity (63,91,92). This assumes that the relationship between the circulatory capacity and oxygen consumption can be predicted (63). This is based on the observations that the circulatory and pulmonary systems respond similarly to the stresses of changing work load (63). A description of the selected test appears in

Appendix D.

PROPOSED DATA ANALYSIS

The primary analysis will be the intercorrelation of the following data:

1. strength tests;
2. strength indices;
3. anthropometric measures;
4. anthropometric indices;
5. models and equations, using both strength and anthropometric measures.

The intercorrelation analysis may reveal significant relationships between certain measures, indices and equations (93). If this occurs, then a simplification of the testing battery and subsequent analysis is possible by replacing those parameters, difficult to assess, with others that are more easily obtained. The result would be a reduction in the total number of measures that are required in the battery.

The main analysis will take the results of the anthropometric measurements, strength tests, calculated indices, models and equations, and correlate these values with the performance scores on the criterion tasks. Where possible, the data showing the highest correlations will be grouped and multiple correlation techniques (93) will be implemented, in an attempt to increase the level of predictability. If the multiple correlations yield greater predictability, regression equations will be calculated (93). The measurements, indices and equations, which show a high predictive relationship with the criterion tasks, will be used in the selection standards for the three CF trades.

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APPENDIX A

STANDARDIZATION OF THE REPORTED DATA

Standardization of the Reported Data

Because of the considerable diversity of data presentation in the literature, standardization of the information that should be encompassed in a report is necessary (57,62). The following is a summary of the important areas that should be included in a report, so that the results may be meaningfully compared to the findings of other studies (18,57,62). It should be noted that the standards apply directly to studies involving static strength tests (18,62).

Describe the conditions of the tests in relation to:
1. body parts and muscles used primarily;
2. body position;
3. body support or reaction force available;
4. coupling of the subject to the measuring device;
5. strength measuring and recording device;
6. method of force exertion;
7. instructions given to the subjects.

Describe the subjects in relation to:
1. population and sample selection;
2. sex;
3. age;
4. medical status;
5. training related to tests;
6. relevant anthropometry and how it was measured.

The presentation of the data should include:
1. mean values;
2. standard deviations;
3. measure of normality or skewness;
4. minimum and maximum values;
5. sample size.

APPENDIX B

DESCRIPTION OF THE STRENGTH TESTS, THE STRENGTH INDICES AND MODELS AND THE STATIC STRENGTH TESTING APPARATUS

Description of the Static Strength Tests

1. right and left grip strength

This is the only static strength test that is not measured by the load cell and the static strength testing apparatus. A hand grip dynamometer, adjusted to the subject's comfortable grip, is used. The subject stands with arms at sides and grips the dynamometer, one hand at a time. Neither the hand, nor the dynamometer should be allowed to touch the subject's body during the exertion.

2. lifting strength

A series of lifts is performed, using both hands in a supine-positioned grip on a bar and the feet kept a shoulder width apart. The subject is situated so that his/her ankles (medial malleoli landmarks) are a horizontal distance of 18 centimeters from the lifting bar. The subject's posture will depend upon the lifting height. The following lifting heights, 40, 81, 110, 140 and 190 centimeters, will test the static strength of the legs, back or torso, arms and shoulders.

3. back extension

The procedure is similar to that reported in Yates, et al. (19) and Kamon and Goldfuss (94). The subject stands upright, facing the apparatus, with feet shoulder width apart. A strap is placed around the subject's shoulders and attached at chest level to the load cell via cable and chain. The subject pulls backward, while stabilized by a board in front of him/her, that extends from the waist to the knees.

4. back flexion

The procedure is similar to the back extension, except the subject faces away from the apparatus. The subject pulls forward, while supported at the buttocks.

5. shoulder flexion (45 degrees)

The procedure is similar to that reported in Yates, et al. (19). The subject stands facing away from the apparatus, with the shoulder kept at a 45 degree angle and the elbow joint fully extended. The angle between the upper arm and the trunk is set with a goniometer. A wrist strap on the right arm, cable and chain are used as the link to the load cell.

6. shoulder flexion (135 degrees)

The procedure is similar to that reported in Yates, et al. (19) The subject sits facing the apparatus.

The back is kept straight and the right shoulder angle is 135 degrees, using the same attachments to the load cell as in the 45 degree shoulder flexion.

7. elbow flexion

The procedure is similar to that reported in Yates, et al. (19) and Kamon and Goldfuss (94). The subject sits facing the apparatus. The right elbow is rested upon a padded support, with the forearm in a vertical, mid-supinated position and the upper arm parallel to the floor. The link to the load cell is via a wrist strap, cable and chain.

8. arm pull

The subject faces the apparatus and stands with feet shoulder width apart. With the right hand in a supine position and the elbow joint angle approximately 155 degrees, the subject pulls towards his/her body, without leaning backwards. A goniometer is used to adjust the angle at the elbow. The link to the load cell is via wrist strap, cable and chain.

Description of the Dynamic Strength Tests

The procedures for the dynamic strength tests are adapted from Ayoub, et al. (6).

1. chin-ups

The subject's body is suspended from a bar, using a backward palms grip. This backward grip allows 2-2.5 more chins on average than the forward grip. A chin is defined as moving from the position of arms extended, to chin over the bar and back to arms extended. No swinging or kicking is permitted and no partial credit is allowed. The exercise should be a continuous procedure. The score is the number of chins successfully completed in 1 minute.

2. push-ups

The test begins with the subject laying on his/her stomach and the hands beside the chest, so that the forearms are perpendicular to the floor. The fingers are pointed forward, the feet are together and the body is kept straight. The push-up differs for the female subjects in that they will support their body weight on their hands and knees and not on their hands and the anterior portions of the feet. The body is raised until the arms are straight and then lowered again, so that only the chin and the chest touch the floor. This is repeated, holding no position any longer than 2 seconds. No partial credit is given and the score is equal to the number of push-ups successfully completed in 1 minute.

3. dips

The subject lifts his/her body between the parallel bars, which have been adjusted to shoulder height and shoulder width. From the arms straight position, the subject lowers his/her body to where the elbow forms a 90 degree angle. The examiner notes this place with a fist, which the subject touches each time a dip is performed. One count is given for mounting the bars and an additional count is given for each time the body is returned to the extended arms position. It is scored as the number of dips successfully completed in 1 minute.

4. sit-ups

The subject lays supine on the floor, with knees flexed at approximately 90 degrees and the feet 30 centimeters apart. The hands, with the fingers interlocked, are placed on the back of the neck and the feet are held down. The subject sits up, touches his/her knees with elbows and then returns to the start position. It is scored as the number of sit-ups successfully completed in 1 minute.

5. vertical leap
With chalked fingers, the subject reaches as high as possible while standing and makes a mark on a scale board. The subject then crouches and leaps as high as possible, making another mark on the scale board. This is repeated for a total of 3 leaps. The score is equal to the distance from the top of the reach mark to the top of the highest leap mark, measured to the nearest centimeter.

Strength Indices and Models

The strength indices and models were adapted from the literature (1,16,19,58-61). The actual formulae comprising the indices and models may be of limited value because they were derived using multiple regression techniques, and the calculated coefficients may be specific to the original, sample populations (93). However, the formulae may be of heuristic value because they isolate certain candidate strength and anthropometry measures, and suggest their possible interrelationships.

The following formulae have been proposed for assessing overall body strength. The strength indices will be determined from the individual tests in the battery and evaluated for their predictive performance on the criterion tasks. The first formula is the Roger's measure of overall strength (58), and the next nine formulae are derivations of it and may prove to be useful simplifications. The last two formulae are measures of arm strength, not overall strength. A measure of arm strength is required in some of the formulae of overall strength. Both of the arm strength equations will be used to calculate that part of the formulae. The authors did not report their measures in the units of the metric system. Therefore, the strength measures and body weights are in pounds and height is in inches.

Composite strength score =

1. grip strength + leg strength (lift) + back strength (lift) + pull-ups (chins) + push-ups (dips) + lung capacity (58)

2. chins (1.000) + dips (0.433) + sum of grips (0.714) + back lift (0.204) + leg lift (0.199) (16)

3. sum of grips + back lift + leg lift (58)

4. leg lift (1.05) + back lift (1.35) + dips (10.92) + 133 (59)

5. leg lift (1.33) + arm strength (1.20) + 286 (59)

6. leg lift (1.12) + arm strength (0.99) + right grip (5.19) + 129 (59)

7. leg lift (1.22) + arm strength (1.23) + 499 (59)

8. leg lift (1.07) + arm strength (1.06) + back lift (1.42) + 194 (59)

Arm strength =

9. [push-ups(dips) + pull-ups(chins)] X [(weight/10) + height - 60] (60)

10. height (1.77) + chins (3.42) - 46 (60)

As stated earlier, both strength and anthropometric measures are used in these models. The first set of models is adapted from Chaffin, et al. (1). They split the movement of lifting into the two categories, lifting above and, below 40 inches. The premise is that different muscle groups will be the primary movers for the lifting action, depending on the vertical height of the lift. For the purpose of this study, the following indices of lifting strength will be calculated and evaluated for their ability to predict lifting performance.

1. lifting strength = 6.25 [arm-shoulder strength/horizontal distance], when the vertical distance is greater than 40 inches and,
2. lifting strength = 10.0 [leg-back strength/horizontal distance], when the vertical distance is less than 40 inches.

The second group of multivariate regression equations, for maximum lifting strength, is based on various anthropometric and strength measurements (19), and have been determined for different lifting heights. Actual maximum static lifting strengths will be measured at each of these heights, to permit comparisons to be made between the predicted and the measured values. Different equations are given for males (M) and females (F), at each of the lifting heights.

At 40 centimeters

$$y = 6016 + EHt\ (202.2) + A\ (38.3) - Ht\ (159.0) \qquad M$$
$$y = 1400 + BE\ (4.5) + SHt\ (33.6) - Ht\ (35.1) \qquad F$$

At 81 centimeters

$$y = -1160 + BE\ (6.9) + KHt\ (22.4) + SF135\ (14.5) \qquad M$$
$$y = -214 + EF\ (22.4) + SF135\ (31.8) - SF45\ (22.7) \qquad F$$

At 110 and 140 centimeters

$$y = -2108 + Ht\ (12.1) + EF\ (10.6) - G\ (2.7) \qquad M$$
$$y = -174 + SF45\ (10.7) + EF\ (6.9) + BE\ (1.8) \qquad F$$

At 190 centimeters

$$y = -1953 + Ht\ (16.6) - G\ (6.8) - E\ to\ F\ (15.7) \qquad M$$
$$y = -99 + EF\ (4.7) + SF135\ (6.1) + BE \qquad F$$

Where;

y = maximum static lifting strength (Newtons)
A = age (years)
BE = back extension (N)
EF = elbow flexion (N)
EHt = elbow height (centimeters)
E to F = elbow to fist length (cm)
G = grip (N)
Ht = height (cm)
KHt = knee height (cm)
SF45 = shoulder flexion at 45 degrees (N)
SF135 = shoulder flexion at 135 degrees (N)
SHt = shoulder height (cm)
Tht = trochanteric height (cm)
Wt = weight (kilograms)

The final equations are models for predicting the isometric strength of males and females (61). The calculated isometric strength values will be compared to the measured lifting strength values, as well as to the data from the other strength tests. The models predict isometric strength at four areas of the body as well as a composite of lifting strength. The authors were not consistent in their use of either metric or English units.

1. shoulder strength = -31.028 - sex code (33.723) - body weight (1.500) - knuckle height (0.874) - iliac crest height (2.187) + chest depth (28.710) + chest width (1.215) + RPI (1.584) + body weight X shoulder height (0.014) - chest depth X chest depth (0.753)

2. leg strength = 212.282 - sex code (48.670) + age (0.704) - chest width (4.968) + body weight X shoulder height (0.005) - abdominal depth X abdominal depth (0.076) + predicted shoulder strength (1.197)

3. arm strength = -80.648 + age (0.688) - shoulder height (0.414) - abdominal depth (2.010) + [ln body weight] (34.264) + predicted shoulder strength (0.622)

4. back strength = -8.274 - age + height (1.850) - knuckle height (3.088) + chest depth X chest depth (0.051) + predicted shoulder height (1.052)

5. composite = -177.435 + iliac crest height (2.116) + chest depth X chest depth (0.116) - abdominal depth X abdominal depth (0.062) + predicted shoulder strength (1.704)

Where;

age is in years
body weight and strength are in pounds
body measurements are in centimeters
sex code = 0 for males and 1 for females
RPI = ht/3 X cube root of body weight

Description of the Static Strength Testing Apparatus

The strength testing apparatus and recording equipment are displayed in Figure 1. The isometric strength testing device was adapted from descriptions and photographs in Yates, et.al. (19) and, Kamon and Goldfuss (94).

The strength testing device consists of two vertical, metal standards and a wood base surrounded by a metal frame. A pulley is attached to a metal cross-piece between the standards. The load cell can be affixed to the wood base, via metal plates, in two places depending upon the test requirements.

A chain, cable and nonstretchable belt provide the connection between the subject and the load cell. The chain is adjustable to allow for use in different tests and with different subjects. The cable will pass over the pulley during a number of the tests. The belt is adjustable and 2 inches in width, as suggested by Chaffin (18). A lifting bar, 12 inches in length and 1 inch in diameter, was made to substitute for the belt in some of the tests. A wooden support for the subject can be mounted on the standards. On top of the wooden support is an elbow rest. The contact surfaces between man and apparatus, such as the elbow rest and the lifting bar, are padded as recommended in the literature (18).

The forces measured by the load cell, with a 500 pound capacity, are all in tension. The output of the load cell is recorded on graph paper by an X-Y plotter, which was modified with a timer so that data could be collected over a period of 5 seconds. To calibrate the apparatus, a series of known weights are suspended from the cable and chain. This provides a calibration factor so that the output recorded on the graph paper can be eventually expressed in the unit Newtons.

Figure 1: The Static Strength Testing Apparatus

APPENDIX C

DESCRIPTION OF THE ANTHROPOMETRIC MEASUREMENTS AND THE ANTHROPOMETRIC INDICES

Description of the Anthropometric Measurements

Descriptions of the anthropometric measures were, in part, taken from the literature (95), and they are illustrated in Figures 2a and 2b. All values were recorded to the nearest 0.1 cm, except the skinfold measures (nearest 0.1 mm) and weight (nearest 0.1 kg). All measures were taken from the right side of the body. The measuring equipment included a weight scale, measuring bench, anthropometer, beam calipers, spreading calipers, skinfold calipers, cloth measuring tape, foot scale and appropriate wall-mounted scales.

1. age

    Recorded in years.

2. gender

    Indicated as a 0 for males and a 1 for females.

3. weight (mass)

    The subject stands erect on medical scales. Weight is recorded to the nearest 0.1 kilograms.

4. stature

    The subject stands erect with line of sight horizontal and heels together. With the arm of the anthropometer touching the scalp in the midsagittal plane, the vertical distance from the standing surface to the top of the head is measured.

5. shoulder height

    The subject stands erect with heels together. The vertical distance from the standing surface to the right acromion landmark is measured with the anthropometer.

6. elbow height

    The subject stands erect with heels together. The vertical distance from the standing surface to the olecranon process (proximal end of the ulna) is measured with the anthropometer.

7. interphalangeal joint height

    The subject stands erect with heels together. The vertical distance from the standing surface to the middle knuckle (second interphalangeal joint) of the right middle finger is measured with the anthropometer.

8. iliocristale height

    The subject stands erect with heels together. The vertical distance from the standing surface to the top of the right ilium, in the mid-axillary plane, is measured with the anthropometer.

9. trochanteric height

The subject stands erect with heels together. The vertical distance from the standing surface to the top of the right greater trochanter is measured with the anthropometer.

10. biacromial breadth

The subject stands erect with heels together and arms relaxed at the sides. The horizontal distance between the two acromial landmarks is measured with the beam calipers.

11. chest breadth

The subject stands erect with heels together and arms slightly abducted. The horizontal chest breadth at nipple height is measured at the average point of quiet respiration, using the beam calipers.

12. biiliocristale breadth

The subject stands erect with heels together and arms at the sides. The horizontal distance between the superior points of the iliac crests, in the mid-axillary plane, is measured using the beam calipers.

13. chest depth

The subject stands erect with heels together and arms at the sides. The horizontal depth of the chest at nipple height is measured at the average point of quiet respiration, using the beam calipers.

14. abdominal depth

The subject stands erect with heels together and is instructed to relax the abdominal muscles. The maximum horizontal depth of the lower torso at the abdomen is measured at the average point of quiet respiration, using the beam calipers.

15. elbow-interphalangeal joint length

The subject sits erect on the measuring bench, with shoulders and upper arms relaxed and the elbows flexed to place the ulnar surfaces of the forearms in the horizontal plane, and parallel. The fingers are flexed at the second interphalangeal joint with the palm facing inward. The horizontal distance from the olecranon to the second interphalangeal joint of the middle finger is measured with the beam calipers.

16. foot length

The subject stands erect with both feet in the foot measuring box and 10 cm apart. The right foot is positioned so that its long axis is parallel to the side of the box, with the heel toughing the rear.

The lateral metatarsal-phalangeal joint is in light contact with the side of the box. A measuring block is held against the tip of the most distal phalanx and the length of the right foot is measured on the foot scale.

17a. relaxed biceps circumference

The subject stands erect with the right arm extended forward horizontally and supported at the wrist so that the biceps brachii is relaxed. With the measuring tape held perpendicular to the long axis of the right arm, the circumference at the bicep landmark is measured.

17b. flexed biceps circumference

The subject stands erect with the right arm extended forward horizontally and the elbow flexed so that the forearm is raised vertically. The subject is instructed to make a fist and maximally contract the biceps brachii while flexing the right elbow to bring the fist in contact with the shoulder. With the measuring tape held perpendicular to the long axis of the right upper arm, the maximum bicep circumference (bicep landmark) is measured.

18. chest circumference

The subject stands erect with arms slightly abducted. The measuring tape is held in the horizontal plane and the circumference of the chest at the nipple height is measured at the average point of quiet respiration.

19. upper thigh circumference

The subject stands erect with heels together and weight distributed equally on both feet. The horizontal circumference of the thigh, just below the gluteal fold, is measured with the measuring tape.

20. calf circumference

The subject stands with heels together and weight distributed equally on both feet. With the measuring tape held horizontally, the maximum circumference of the lower leg measured.

21. humerus diameter

The subject sits erect with the right arm extended forward horizontally, the elbow flexed and the forearm raised vertically. The distance between the lateral and medial epicondyles of the humerus is measured with the spreading calipers. Slight pressure is exerted on the caliper tips to compress the soft tissue.

22. femur diameter

The subject sits on the measuring bench with feet supported so that the thighs are in the horizontal plane and parallel. The lower leg is vertical, with the popliteal in light contact with the front edge of the bench. The distance between the lateral and medial epicondyles of the femur is measured with the spreading clipers. Slight pressure is exerted on the caliper tips to compress the soft tissue.

23. seated height

The subject sits erect on the measuring bench with line of sight horizontal and the arms resting lightly on the thighs. The feet are supported so that the thighs horizontal and parallel. With the arm of the anthropometer touching the scalp in the midsagittal plane, the vertical distance from the sitting surface to the top of the head is measured.

24. seated eye height

The subject sits erect on the measuring bench with line of sight horizontal and the arms resting lightly on the thighs. The feet are supported so that the thighs are horizontal and parallel. The vertical distance from the sitting surface to the right pupil is measured with the anthropometer.

25. knee height

The subject sits erect on the measuring bench with feet supported to that the thighs are horizontal and parallel. The lower legs are vertical (knees bent to 90 degrees) with both popliteal in light contact with the front edge of the bench. The vertical distance from the foot surface to the superior aspect of the right patella is measured with the anthropometer.

26. popliteal height

The subject sits erect on the measuring bench with feet supported so that the thighs are horizontal and parallel. The lower legs are vertical (knees bent to 90 degrees) with both popliteal in light contact with the front edge of the bench. The vertical distance from the foot surface to the underside of the thigh immediately behind the knee (as measured from the floor to the sitting surface) is measured with the anthropometer.

27. buttock-popliteal length

The subject sits erect on the measuring bench with feet supported so that the thighs are horizontal and parallel. The lower legs are vertical with both popliteal surfaces in light contact with the front edge of the bench. A measuring block is held against the most posterior aspect of the right buttock and the horizontal distance from the front edge of the bench to the measuring block is read from the bench scale.

28. forward functional reach (standing)
    The subject stands erect in a corner with the back against one wall and the right arm extended forward horizontally along the other wall. The right hand is pronated and fingers clenched to form a fist. The thumb is then fully extended below the fist, in horizontal line with the forearm. The heels, buttocks and shoulders are held firmly against the wall and a measuring block is held against the tip of the extended thumb. The horizontal distance from the back wall to the block is measured on the wall scale.

29. overhead reach
    The subject stands erect with heels together and buttocks and shoulders against the wall. The right arm is extended vertically upward, while the heels remain in contact with the standing surface. With the right arm fully extended, the tips of the fingers are used to push a measuring block up to wall to a maximum vertical height. The vertical distance from the standing surface to the block is measured on the wall scale.

30. functional leg length
    The subject sits on the extreme edge of tne measuring bench with the right leg fully extended forward. The heel rests on the floor and the foot is maximally dorsiflexed. The subject then sits erect and the distance from the plantar surface of the foot to the posterior waist landmark, along the long axis of the leg, is measured with the anthropometer. The measured distance is corrected by subtracting 1.3 cm to allow for the thickness of the perpendicular surface attached at the base of the anthropometer.

31. biceps skinfold
    The subject stands erect with arms relaxed at sides. The thickness of a skinfold on the front of the arm, midway between the elbow and acromion, is picked up parallel to the long axis of the upper arm. It is measured using skinfold calipers.

32. triceps skinfold
    The subject stands erect with arms relaxed at sides. The thickness of a skinfold on the back of the arm, midway between the acromion and the olecranon process, is picked up parallel to the long axis of the upper arm. It is measured using skinfold calipers.

33. subscapular skinfold

The subject stands erect with arms relaxed at sides. The thickness of a skinfold is picked up just below the inferior angle of the scapula and parallel to the natural cleavage line of the skin. It is measured using skinfold calipers.

34. suprailiac skinfold

The subject stands erect with arms relaxed at sides. The thickness of a skinfold is picked up above the iliac crest which is palpable anterior to the midaxillary line. The measurement is taken parallel to the natural cleavage of the skin using skinfold calipers.

35. calf skinfold

The subject stands on the left leg, the right knee bent to 90 degrees and supported on the measuring bench. The thickness of a skinfold is picked up on the medial surface of the calf at the region of maximum circumference. The measurement is taken parallel to the long axis of the lower leg, using skinfold calipers.

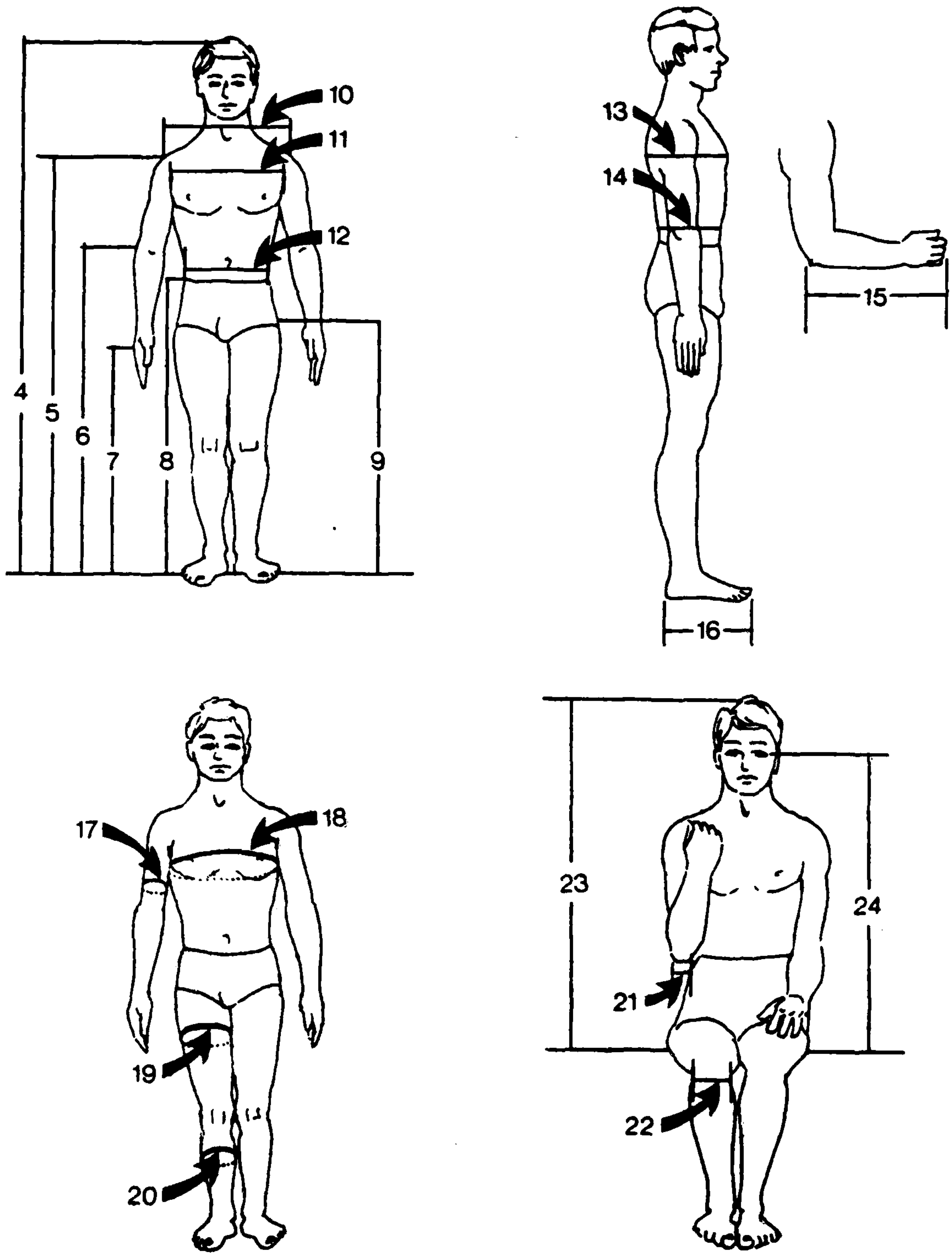

Figure 2a: The Anthropometric Measurements

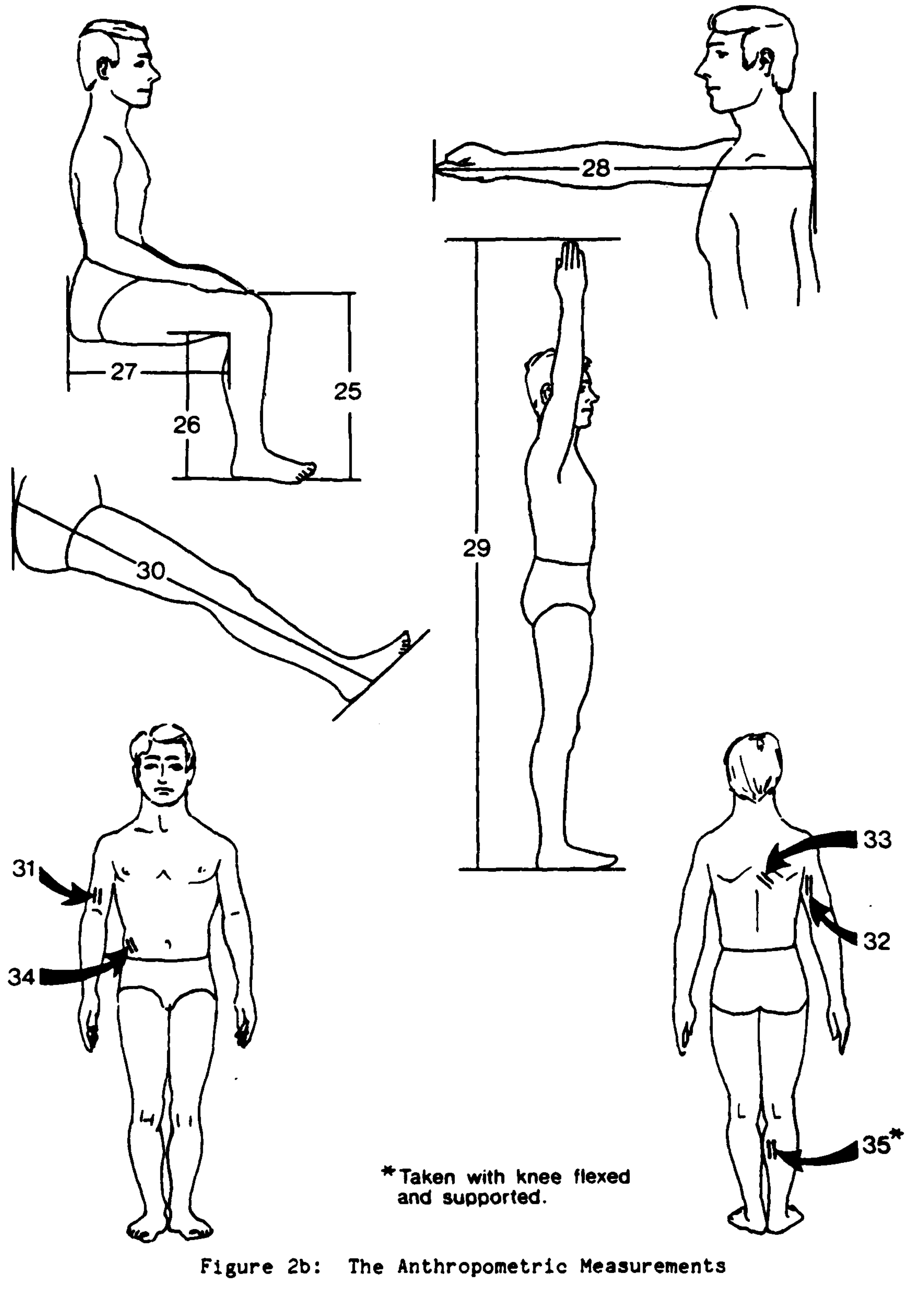

Figure 2b: The Anthropometric Measurements

Anthropometric Indices

The following are anthropometric indices, which may be useful in prediction of certain strength measures.

1. ponderal index = stature X the cube root of weight (81)
2. index = upper arm circumference/thigh circumference (81)
3. index = chest circumference X stature (81)
4. index = biacromial breadth/biiliocristale breadth (81)
5. index = chest circumference/weight (81)
6. index = stature/weight (81)
7. index = thigh circumference/femoral breadth (59)
8. index = biiliocristale breadth + foot length (68)
9. index = chest circumference (20.02) + humeral width (175.88) + femoral width (85.91) - 1529 (80)

APPENDIX D

DESCRIPTION OF THE ENDURANCE TEST

Description of the Endurance Test

A step test will be used to evaluate, indirectly, each subject's maximum aerobic capacity. The following procedures, for the step test, were outlined in Bell and Beretta (96).

1. Three heart-rate monitoring electrodes are placed on the subject's chest.

2. A seated, resting heart rate is taken prior to stepping. The step test begins if the there are no apparent abnormalities in the resting trace and if the rate did not exceed 95 beats per minute.

3. If the pre-exercise heart rate is above 95 beats per minute, the subject is asked to relax until the heart rate decreases.

4. The step height for males is 40 centimeters and 33 centimeters, for females.

5. One, two or three step sequences, each four minutes in length, are performed consecutively, with a one-minute rest period between tests and with the rate of ascent increasing from 18 to 24 to 30 cycles per minute.

6. The heart rate is recorded during the last 15 seconds of each stepping period. A heart rate in excess of 140 beats per minute signals the end of the test.

7. The oxygen cost of the stepping activity is determined using the equations of Nagel, et.al. (91). Once the oxygen cost of the activity is determined, the maximum oxygen uptake is predicted using a formula by Shephard (92).

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